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SEGMENTATION OF X-RAY TOMOGRAPHIC IMAGES: CONTIBUTION TO WEATHERING ANALYSIS OF BUILDING LIMESTONES ORIGINATING FROM HISTORICAL BUILDINGS

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Historical monuments contributing to our cultural heritage undergo their environment that alters them and can results in their destruction. The observed macro-scale effects result from physico-chemical mechanisms (dissolution, transport, precipitation) occurring in the complex porous structure of the building stones at the pore scale. Understanding of weathering processes and more generally of water transfer properties of building stone requires a detailed knowledge of the pore and different solid phases distribution. Indeed, quantitative physical models (permeability, compressive strength…) rely on a precise and relevant description of the microstructure. The method presented here is a required step toward the understanding of the mechanisms of limestones weathering based on realistic geometrical information of the geomaterial, i.e. not based on a more or less complex mathematical model representing an ideal material.

Thus, it is important to characterize stones originating from carriers (unweathered) and from weathered buildings as an initial step of research. X-ray microtomography enables to achieve such a goal and to obtain relevant geometrical and topological information. However it requires the identification of the phases constituting the stone: the void space (impregnated with resin here) on one hand and the different mineral phases (mainly calcite and silica) on the other hand. This segmentation step is of major importance to assure the quality of the approach. In the case of low contrast images of multiphasic medium this analysis requires particular attention. The complexity of the structure of the considered limestone (tuffeau), the low contrast X-ray absorption of its phases and the measurement noise do not allow a simple and immediate segmentation (figure 1). Hence we propose a new approach in the field of building stone conservation based on mathematical morphology (Serra, 1982, 1988). The versatile set of tools provided by mathematical morphology (permitting to take into account notions such as shape or neighbourhood between objects) allows us to achieve a precise segmentation of tuffeau tomographic images.

The approach is divided in two steps. First an alternative sequential filter (an ordered succession of opening and closing of increasing size) is applied to minimise the noise. As the low X-ray absorption contrast does not yet allow the segmentation of the three main phases (calcite, silica, resin), a second step is required. A geodesic operator based on the watershed of the morphological gradient of the image is used to obtain a mosaic of flat zones (Beucher, 1990). The use of the gradient ensures that we correctly extract the boundaries between the objects, whatever their shape and size. As a result, this mosaic is actually a simpler image that can straightforwardly be segmented by thresholding (figure 2).

The application of the segmentation method to different weathered samples (from the surface of building limestones) and unweathered samples (either from carrier or from the heart of building limestones), enables to observe the modification of structure and phase composition involved by weathering. As a perspective we shall use the structural information extracted from the images of real samples to feed a physical model of fluid transport.

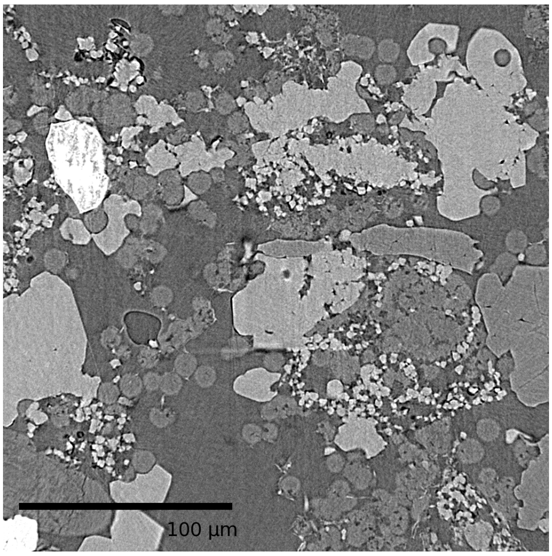

Figure 1: *2-D slice (1024 X 1024 pixels, pixel size: 0.28 µm) of quarry Tuffeau: grey levels allow to distinguish the different components: grey light: calcite, dark grey: silica, black: porosity.*

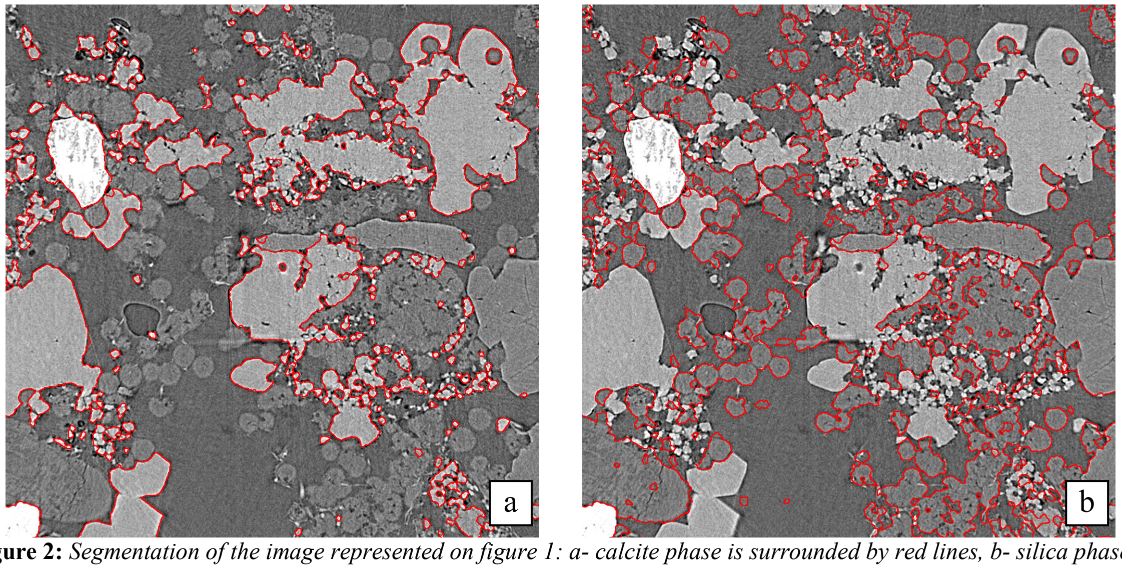

Figure 2: *Segmentation of the image represented on figure 1: a- calcite phase is surrounded by red lines, b- silica phase is surrounded by red lines.*

References

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